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Guidelines for sampling and describing the soils of Al Damar in the River Nile State, Sudan

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Disclaimer:

ACKNOWLEDGEMENT

Soil survey, sampling and laboratory analysis will be carried out in Al Damar locality of the River Nile State in Sudan under the auspices of the United Nations Climate Technology Centre and Network through a project titled: *soil erosion evaluation using advanced laboratory measurement methods to support climate-resilient agriculture and food security*. The support and invaluable contributions provided by all stakeholders, especially the Technical Working Group based in Sudan, in the production of this field guide is greatly appreciated. Special thanks are also extended to the Director General - RCMRD for the administrative and logistical support, as well as for guidance throughout the process.

30th June, 2023

ABBREVIATIONS

4WD	Four wheel drive
AAS	Atomic absorption spectroscopy/ spectrophotometer
AfSIS	Africa soil information service
CS-SLM	Climate-smart sustainable land management
CTCN	United Nations Climate Technology Centre and Network
DEM	Digital elevation model
EO	Earth observation
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical information systems
GPS	Global positioning system
NRGD	Natural Resources General Directorate of the Ministry of Agriculture and Forests
PSM	Predictive soil modelling
RCMRD	Regional Center for Mapping of Resources for Development
RNS	River Nile State
SWALIM	Somalia water and land information management
TA	Technical assistance
TWG	Technical working group
UAV	Unmanned aerial vehicle (also known as drone)
USDA	United States Department of Agriculture
WRB	World Reference Base of soil classification

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1.0 INTRODUCTION

1.1 Background and Context

The increasing frequency of climatic extremes, particularly droughts, high-velocity wind storms, erratic rainfall, and floods has exposed the northern parts of Sudan to both wind and water erosion. Anthropogenic factors, such as inappropriate land use practices and over-exploitation of natural resources have also accelerated the soil erosion rates. This has, in turn, affected the productivity of the grazing and agricultural lands, rural livelihoods, and food and nutrition security in the country. However, these impacts are still not well-understood due to the complex nexus between climate change and land degradation, and a lack of biophysical soil health indicators and standardized methodological framework for evaluating soil erosion and its effects on crops.

To address the foregoing issues, the Natural Resources General Directorate of the Ministry of Agriculture and Forests (NRGD) in Sudan sought and received Technical Assistance (TA) from the United Nations Climate Technology Centre and Network (CTCN) to evaluate soil erosion and the attendant effects on functional soil properties using advanced soil analysis, Earth Observation (EO) and Predictive Soil Modelling (PSM) technologies (e.g., atomic absorption spectroscopy [AAS] and Unmanned Aerial Vehicles [UAVs]) to support climate-resilient agriculture and food security in Sudan. In particular, the NRGD intends to map the spatial patterns of soil erosion risk and functional soil properties (e.g., soil organic carbon, pH and micro-nutrients), quantify the annual soil loss rates, and delineate the priority areas for Climate-Smart and Sustainable Land Management (CS-SLM).

The predictive soil models that will be developed and applied by the TA to provide spatially-explicit information on soil erosion and functional soil attributes require detailed and accurate soil data, which are not readily available in Sudan. Therefore, as an integral activity, soil survey will be executed under this TA to generate the requisite soil data, and will entail describing the soil surface and profile characteristics, collecting samples for physical and chemical analysis at the laboratory, and classifying the soils.

This document has been developed to guide and provide specifications for field survey planning, soil data collection and field observations. During its preparation, literature describing the protocols and approaches adopted by previous soil inventory and mapping projects, such as FAO-SWALIM and AfSIS (FAO-SWALIM, 2007; Vågen et al., 2010) were reviewed, and experienced pedologists with years of accumulated knowledge were consulted.

2.0 GEOGRAPHIC SCOPE

The soil survey is to be conducted in Al Damar (Ad Damer, Ed Damer) District of the River Nile State (RNS), which lies between Latitudes 17° 11' 9.6" and 18° 6' 46.8" N, and Longitudes 32° 28' 12" and 33° 59' 45.6" E, at an altitude of 1,158 feet (353 m) above sea level (Figure 1). It covers an area of 10,866 km², which is dominated by Aridisols (i.e., dry soils with $CaCO_3$ accumulations), semi-desert vegetation (i.e., scrubs and grasslands) and semi-arid climatic conditions.

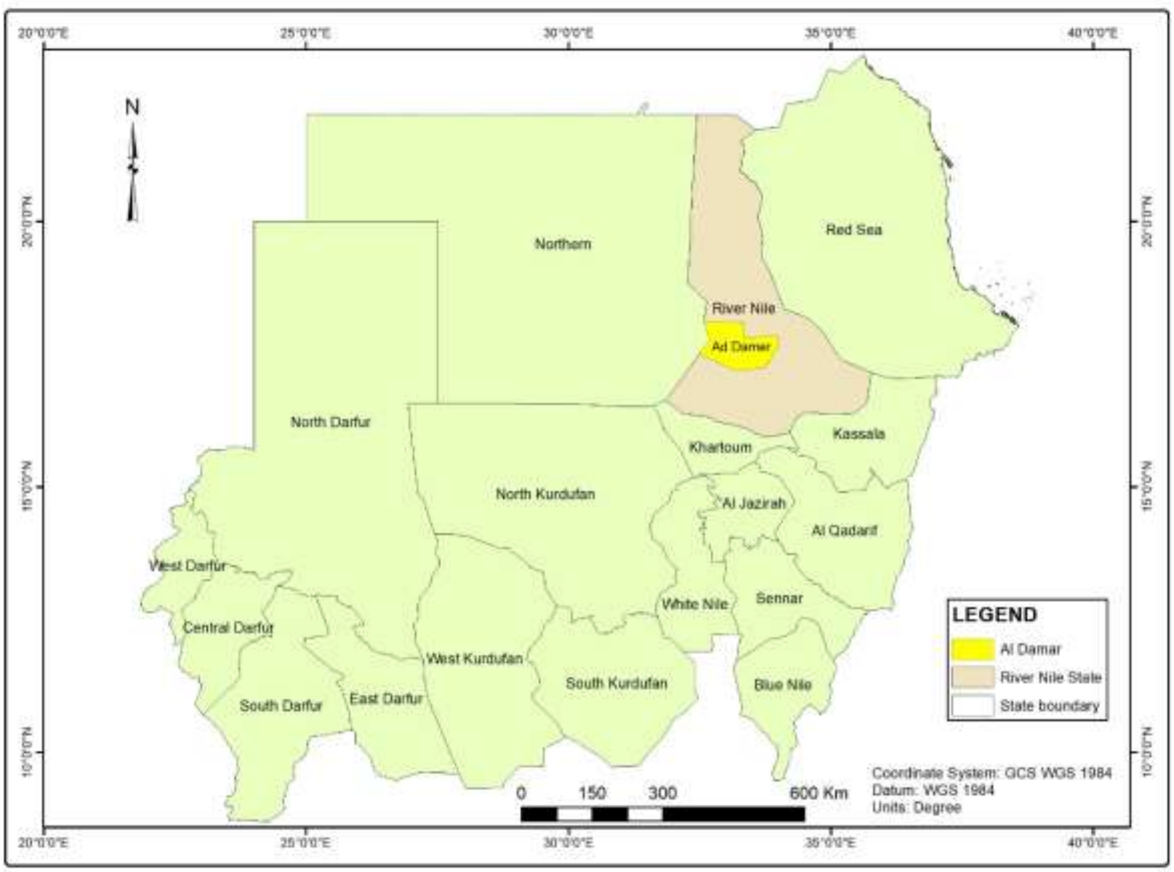

Figure 1: Location of Al Damar District in the River Nile State, Sudan

3.0 PLANNING OF THE SOIL SURVEY

Success of the planned soil survey campaign hinges upon proper preparations. This entails performing and considering a number of things before fieldwork as described in the subsequent sub-sections.

3.1 Constituting the Soil Survey Team

The soil survey team should consist of soil surveyors, a team leader and casual labourers. Both the team leader and soil surveyors should be technically fit and knowledgeable on soil survey matters; however, it is the leader who should plan the daily field activities and soil survey routes, as well as take full responsibility for the team. The casual labourers should be hired in the field to execute tasks, such as digging the profile pits and sampling the soils.

3.2 Collecting Background Data and Information

Before anything else, the constituted team should have a good understanding of the physical and social characteristics of the entire survey area, including the topography, climate, vegetation, geology, land use, major soils and their patterns of occurrence, accessibility and security situation. This understanding can be achieved through a review of pre-existing information and a brief reconnaissance trip to the area before soil mapping begins.

Some of the background and preliminary information and data that should be collected for reference include: aerial photographs, satellite imagery, Digital Elevation Model (DEM), land resource maps (i.e., topographical, geological, soils and vegetation), long-term weather station data, and government statistics. From these data, topographical (physiographic) and other relevant base maps should be prepared, printed and used to delineate tentative soil mapping unit boundaries, which can be revised later on the basis of field observations.

During the brief reconnaissance trip, the team should establish local contacts, make agreements, check the validity of the topographical map, and determine the major soils and probable soil mapping units.

3.3 Developing the Sampling Design

Soil samples should be collected at two hierarchical levels, each with different observation density. The first level of sampling should cover the whole of Al Damar District using reconnaissance type of soil survey, whereas the second level should only focus on the Food Security Project site within Al Damar using semi-detailed type of soil survey.

At the Food Security Project site (~5,042 ha), a semi-detailed soil survey should be conducted at a scale of 1:50,000 by both soil auger and profile pits. Observations by soil auger should be performed up to a depth of 60 cm (or to a hindering layer) in a grid pattern, with one observation for every 25 ha and a spacing of 500 m between observations, while observations by soil profile pits should be up to a depth of 2m (if the bedrock and ground water table permits) at representative sites within the defined mapping units.

In Al Damar District (~10,866 km^2), a reconnaissance soil survey should be conducted at a scale of 1:250,000 and field observations be made by soil auger and profile pits (if time and resources allow). The auger borings should be made at random sites to a depth of 60 cm (or to a hindering layer), with one observation for every 2,500 ha or slightly more. The distribution of the auger observation sites should consider the spatial differences in physiography, geology, land use and soil types. Therefore, while in the office, ancillary geospatial data, including aerial photos, satellite imagery and DEM should be compiled and superimposed to stratify the landscape into mapping units with similar combinations of relief, soil types, land use and geology for the randomization of the auger observation sites.

3.4 Loading the Sampling Site Coordinates into a GPS Device

The coordinates of all the randomized auger observation sites should be loaded into a handheld GPS receiver that is to be used for navigation in the field.

3.5 Collating Materials, Equipment and Office Supplies

The requisite technical equipment and materials should be procured and checked before leaving for fieldwork. These include: soil auger (spade, shovel or backhoe), steel measuring tape, Munsell® soil color chart, achromatic hand lens, geologist's hammer, large knife, trowel, compass, clinometer, hand-held global positioning system (GPS) receiver, GPS batteries, camera, plastic sample bags, labelling tags, thread (string ties), plastic buckets, gunny bags, FAO guidelines for soil description, USDA keys to soil taxonomy, and standard profile and auger description forms (see Appendix 1). If need be, essential personal equipment, such as sleeping bags, toiletries, flashlight, field attire (e.g., boots, sun glasses and hats), cooking and eating utensils should also be checked. Similarly, office supplies and stationeries, such as note books, pencils, pens, permanent markers, rubber bands, paper clips, and staplers should be made available.

3.6 Timing the Soil Survey Campaign

The soil survey should be conducted when the rains are minimal and the soils are neither too dry nor hard for sampling.

3.7 Transport

Since the soil survey team will traverse all kinds of terrain, the four-wheel drive (4WD) vehicle(s) to be used should be in perfect condition. The necessary repairs should be done before departure to the field.

3.8 Safety and Security

The team should carry a first aid kit containing bandages, gauze, cotton, alcohol, wound-dressing solutions, aromatic spirit of ammonia, and some tablets for the most common ailments and pain.

In addition, the local authorities, community leaders and farmers should be informed about the purpose of the soil campaign and their consent sought before sampling. If possible, the team should also take their telephone numbers.

4.0 EXECUTION OF THE SOIL SURVEY

4.1 Navigating to the Soil Sampling Sites

While in the field, the GPS device should be turned on to show the direction and distance to each sampling site that had been loaded into it. Topographic maps and Google Map app could also be used for this purpose. Upon arrival at each random sampling site, the sampling plot should be laid out, sampled for chemical and physical analysis and fully described.

4.2 Making Observations by Soil Auger

4.2.1 Demarcating the Sampling Plot

The plot for sampling soils should be a square, measuring 5 m x 5 m (Figure 2a).

4.2.2 Sampling the Soils and Describing the Site

Soil samples should be collected at the centre and four corners of the plot using an auger (Figure 2b). Prior to sampling, any litter or vegetation at the sampling point should be removed. Thereafter, samples should be taken at two depths; that is, at 0 - 30 cm (topsoil) and 30 - 60 cm (subsoil) depths. The topsoil samples should be the first to be collected from all the five locations within the plot. The collected topsoil samples should be put in a bucket for topsoils, mixed thoroughly using a trowel to form a composite sample, from which about 500 gm of soil should be taken and placed in a well-labelled plastic bag (Figure 3) for transportation to the Central Soil Laboratory of the NRGD for chemical and physical analyses. When done with the topsoil, the soil auger should be cleaned using either grass or leaves, and any topsoil that might have fallen into the auger hole should be removed. The subsoil should be sampled following the same process, but bulked and mixed together in a bucket designated for the subsoils.

Apart from soil sampling, general information and site characteristics, such as observation ID, date, surveyor's name, location (GPS coordinates), climate, elevation, landform, lithology (parent material), slope gradient, slope aspect, (macro-, meso- and micro-) relief, drainage, flooding, depth of ground water table, surface sealing, crusting, cracking, presence of salts, rockiness (rock outcrops), stoniness, erosion, vegetation, land use, and human influence should be recorded on a standard auger hole description form. Characteristics of the soils taken from different depths, including colour, drainage, texture, structure (peds), compaction, consistence (strength), concentrations, coatings, mottles, rock fragments, porosity (voids), and biological features (e.g., soil fauna, root distribution, presence and abundance) should also be described on the form following the FAO guidelines for soil description (FAO-UNESCO, 1997; FAO, 2006; FAO-SWALIM, 2007).

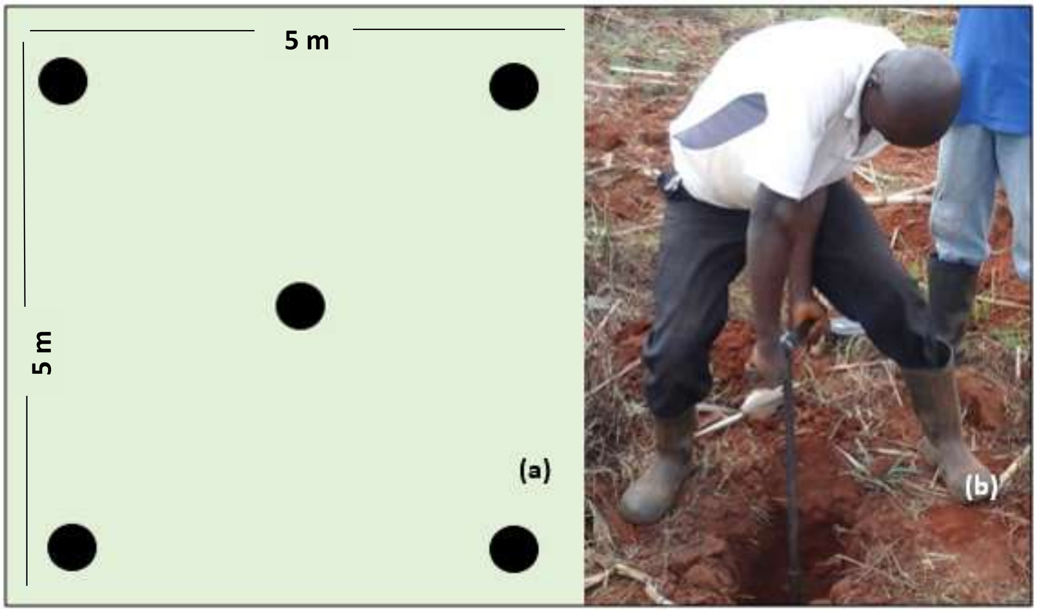

Figure 2: (a) Sampling plot layout; (b) Sampling with an auger - the soil auger should be drilled into the soil, while being turned clockwise. After reaching the required depth, it should be pulled up carefully to keep the soil in place, and the soil sample is to be placed on a sheet of paper or plastic for description

Figure 3: The soil samples should be double-bagged, labelled properly and put in the right bucket

4.2.4 Packing and Labelling Samples

All soil samples should be packed in double plastic bags to reduce the possibility of tears, punctures and moisture loss. Each soil sample package should be labelled carefully and completely using a permanent marker to minimize the risk of losing the labelling tags or not being able to identify the soils (Figure 3). Two labelling tags should be used, one of which should be inserted between the inner and the outer bag. Information on the tags should include the observation ID, sampling depth, name of surveyors and date of sampling. Ultimately, the plastic bags should be tied with strings (or stapled) and placed in the appropriate plastic bucket or gunny bag. That is, the topsoil plastic bucket or gunny bag should just contain topsoil samples from the sampling points. The same case should apply for the subsoil samples.

4.3 Making Observations by Soil Profile Pit

The soil auger observations should be examined and characterized to delineate different soil mapping units within the survey area. Thereafter, representative soil profile pits should be sited and dug within the soil mapping units (i.e., one profile pit per mapping unit).

4.3.1 Selecting and Describing the Site

The profile pits should be purposely sited at places with soil characteristics that are representative and typical of the mapping units. The selected sites should: (i) not be on the boundary of two geomorphological units or land uses, (ii) be away from human and animal disturbances, such as roads and manures, and (iii) have the approval of the land owner.

At the site, general information and characteristics, such as observation ID, date, surveyor's name, location (GPS coordinates), climate, elevation, landform, lithology (parent material), slope gradient, slope aspect, (macro-, meso- and micro-) relief, drainage, flooding, depth of ground water table, surface sealing, crusting, cracking, presence of salts, rockiness (rock outcrops), stoniness, erosion, vegetation, land use, and human influence should be recorded on a standard soil profile description form.

4.3.2 Excavating the Soil Profile Pit

The pit to be dug should be large enough to allow for observations and description of the soil profile (Figure 4). First of all, any litter around the selected site should be removed. After that, a pit should be dug, the dimensions of which should be approximately 0.5 m wide × 1.5 m long × 2 m deep. To avoid distortions of the observed color and other morphological properties, the sampling side of the pit should face the sun; that is, towards the east in the morning and towards the west in the afternoon. The sampling side should be smooth and neat, and the ground surface behind it should be protected from any disturbances, such as footsteps, tools and soils. It can be cleaned of all loose materials using a trowel or a knife; however, it should not be completely smoothened to allow for observations of soil structure, gravel and root development. While digging, soil should be thrown to one side of the pit. A few steps could be cut into the pit to ease access, digging and sampling.

Figure 4: An excavated soil profile

When the pit is ready, the horizon boundaries should be marked, a tape hang on the left side of the sampling face, and a label with the pit ID and date placed above the tape. Lastly, a photograph should be taken using a steady camera.

4.3.3 Describing and Sampling the Soil Profile

After recording the surface characteristics, and cleaning the sides and taking a photograph, the profile should be described in detail based on the genetic horizons, starting from the surface to the bottom of the pit. The description should include the depth, horizon, colour, drainage, texture, structure (peds), compaction, consistence (strength), concentrations, coatings, mottles, rock fragments, porosity (voids), and biological features (e.g., soil fauna, root distribution, presence and abundance) of the soils. The conventions used for soil description have been described in FAO (2006) and Soil Survey Staff (1999).

Sampling of the soil profile for soil chemical and physical analysis should also be done horizon by horizon. The samples should be taken from the central part of each genetic horizon using a trowel (Figure 5), starting with the lowest horizon working upwards to avoid contamination.

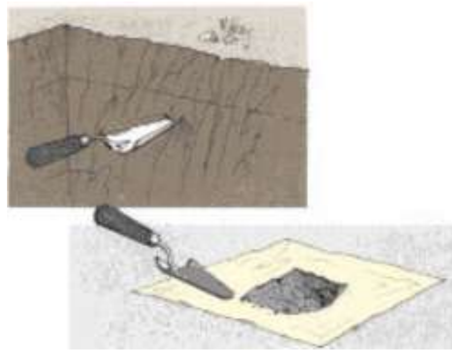

Figure 5: Taking a soil sample from a profile (*Source:* www.fao.org)

Finally, the soil profiles should be tentatively classified based on the field data using the USDA soil taxonomy system (Soil Survey Staff, 1999). But once the laboratory data are out, the final soil classification should be made.

4.3.4 Packing and Labelling Samples

The soil samples from each genetic horizon should be packed and labelled according to the procedures described in Section 4.2.4; however, information on horizon designation should also be included on the labelling tags.

4.4 Leaving the Soil Sampling Sites

Before leaving the site, the team leader should ensure that the samples taken and equipment used at the site have been accounted for, the profile description and sample record sheets have been exhaustively filled, and the site is in neat and clean condition. Any litter, including plastics and papers should be removed, and the auger holes and profile pits covered with soil.

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APPENDICES

Appendix 1: Checklist of field equipment and materials

Equipment	Use
Soil auger (spade, shovel or backhoe)	Digging and soil sampling
Steel measuring tape	Determining horizon depth
Munsell® soil color chart	Determining soil colour
Achromatic hand lens	Examining cutans and individual soil grains
Geologist's hammer	Cracking rocks
(Large) knife	Sampling soils from the genetic horizons, cleaning the sides of a soil profile pit
Trowel	Mixing soil samples, sampling soils from the genetic horizons, cleaning the sides of a soil profile pit
Machete	Clearing bushes
Clinometer	Determining slope gradient
Compass, hand-held GPS receiver (and GPS batteries)	Field navigation
Camera	Capturing the morphology of the soil profiles
Plastic sample bags	Packing the collected samples
Labelling tags	Labelling soil samples in the plastic bags
Plastic buckets	Mixing soil samples
Gunny bags (plastic crates or cartons)	Carrying and transporting the packed and labelled soil samples
Thread (string ties)	Tying up the plastic sample bags
FAO guidelines for soil description and USDA keys to soil taxonomy	Reference while examining soils
Office supplies (writing pad, pen, permanent marker, clip board, etc.)	Recording field notes, writing labels on sample bags, etc.
Topographic, geological and soil maps	Field reference
Profile and auger description forms	Recording site and soil characteristics at the sampling units